Title

‘Celtic Cowboys’ reborn: application of multi-isotopic analysis ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$) to examine mobility and movement of animals within an Iron Age British society

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Keywords

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Highlights

- $\delta^{34}S$ analysis reveals more mobility in the Iron Age than previously considered
- Cattle may have been moved over distances greater than 100 km to sites in Wessex
- Routine $\delta^{34}S$ analysis with ^{14}C-dating critical to development of $\delta^{34}S$ isoscapes

Abstract

This paper presents the results of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ isotope analyses on archaeological faunal remains from deposits dated *c.* 400–200 cal BC at two Iron Age sites in Wessex: Suddern Farm and Danebury hillfort, Hampshire. The aim was to investigate diet and mobility within the populations and across a range of animal species. The results demonstrate a significant level of mobility within the Iron Age, with around 20% of the terrestrial herbivores either having been reared off the chalkland and brought to the sites from perhaps 150–200 km away or moving between isotopically distinct areas throughout much of their life and presenting a 'mixed' isotopic signal. The results lead us to suggest that the old paradigm that views most Iron Age people as leading relatively sedentary lives should be re-evaluated, and new models be considered that allow for regular movements by a portion of the population over much larger distances than hitherto considered in this period of prehistory.

1 Introduction

The word *cowboy* evokes pop culture-influenced visions of men on horseback in the American 'Old West' traversing large distances with their herds, or in search of a herd from which to rustle a few head of cattle. The term 'Celtic cowboy' was famously coined by Stuart Piggott (1958) to describe the Iron Age peoples of northern Britain, who at that era were thought to be mainly pastoralists, in contrast to the settled farmers in the south. With the advent of direct evidence of cereal cultivation, Piggott's model of groups constantly on the move and raiding each other's flocks and herds was long ago discarded (van der Veen 1992; Jones 1996). The inhabitants of northern Britain are now seen as settled farmers no different to those in other regions, apart perhaps from making transhumant use of upland pasture for seasonal grazing.

The term cowboy has however reappeared, but this time in Wessex, where Barry Cunliffe (2004) used it to characterize early 1st millennium BC communities, whom he saw as akin to ranchers creating and using the patchwork of linear earthworks and field systems for managing their livestock. For the most part, however, the Iron Age inhabitants of Wessex are viewed as typical subsistence farmers, living in extended families in small enclosed settlements, and focused on a mixed agricultural strategy within a relatively confined environment (Sharples 2010). For example, the inhabitants of Winnall Down (Hampshire) are thought to have produced little excess beyond perhaps grain that they traded with their local hillfort (Fasham 1985), while at Gussage All Saints (Dorset), the occupants are considered to have produced enough foodstuffs and wool to trade for ceramics and querns from production sites 15–20 km away (Wainwright 1979). Moving northward into Oxfordshire, the interpretation is one of highly localized exchange networks akin to medieval parishes, as in the Stanton Harcourt area (Lambrick and Allen 2004), although some sites have evidence for long-distance trade, as at Yarnton, where Droitwich briquetage indicates salt was brought to the site from over 100 km away (Hey et al. 2011).

Following Cunliffe's 40-year programme of research at Danebury hillfort and 15 nearby sites, this hillfort and its environs dominate existing narratives of Iron Age economic and social organization. Depending on whose model one adopts, Danebury was either a large, permanently occupied settlement from which the elite ruled (Cunliffe 1995), or – if we accept Hill's (1995) view that there were essentially no elites – a central location where a wider community periodically gathered (Stopford 1987). In both reconstructions, the hillfort remains the focus for the non-mobile farming families who formed the backbone of the Iron Age socio-economic system. Mobility of people or produce is seen very much as an exception rather than the rule. There are signs that things were starting to change at the end of the Iron Age, as sites were integrated into new cross-Channel trade networks bound up with Roman expansion, but as yet the evidence is limited to a handful of sites (van der Veen and Jones 2007; Minniti et al 2014).

The research presented here challenges this notion of non-mobile Iron Age farmers in Wessex. Stable isotope analyses ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$) on terrestrial herbivores (cattle, horse, and sheep) were initially undertaken directly in conjunction with a large-scale programme of radiocarbon dating and Bayesian chronological modelling, such that all bone samples being dated from one site had their $\delta^{34}S$ values measured in addition to the standard complement of $\delta^{13}C$ and $\delta^{15}N$ measurements. These data were supplemented by a further study on additional terrestrial herbivore samples, and the results are used here as a proxy for the movement of people through the landscape. Having used the data to determine the relative level of mobility, which we define as multiple movements throughout life, we present an alternative view of Iron Age farming, which sees the occupants of some of these sites engaged in a system of subsistence economy stretching well beyond the area controlled or dominated by a single hillfort.

2 Context

2.1 Research background

As part of the Leverhulme-funded *(Re)Dating Danebury* project, carbon, nitrogen and sulphur isotope analyses were applied to faunal remains undergoing radiocarbon dating from the Iron Age site at Suddern Farm, Hampshire (Cunliffe and Poole 2000). The purpose of the study was to investigate the interpretative value of broadly applying sulphur isotope analysis to bone collagen samples that were being radiocarbon dated and to develop new insights into questions of residence and mobility in this specific animal population, dated to the period 400–200 cal BC. The preliminary results led to the work being extended to material from nearby Danebury that was either radiocarbon dated or phased to the same 200-year period. This allowed for a comparison between two settlements with different morphological character and material culture remains, that presumably fulfilled different functions within this society. Another aim of this wider study was to determine if these new data could better inform our understanding of dietary stable isotope values and social organization. The goal has been to shift the focus away from the standard dietary complement of carbon and nitrogen, and to show how sulphur isotope analysis can open the door to exciting new narratives not only about entire populations, but also about the individuals from which they are formed.

2.2 Methodological background and stable isotopes

Skeletal remains offer insights into how past people and animals lived their lives. At the visual level, they can be used to reconstruct population demographics, while at the extracellular level, isotopic analyses allow us to unlock information related directly to diet, and, by extension, residence and mobility. Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analyses are considered the standard tools for reconstructing past human diet (Muldner 2013); their utility for investigating animal diet has also been widely demonstrated (Pearson et al. 2007; Towers et al. 2011; Fuller et al. 2012; Gillis et al. 2013; Stevens et al. 2013b; Jones and Mulville 2016).

Palaeodietary studies are not limited to carbon and nitrogen isotope analysis, and over the past 15 years sulphur isotope analysis has been utilized better to inform on the diet and movement of animals and humans (Richards et al. 2001; Vika 2009; Craig et al. 2010; Oelze et al. 2012), and to explore variabilities in terrestrial-, marine- and freshwater-based diets (Craig et al. 2006; Privat et al. 2007; Nehlich et al. 2010; Lamb et al. 2012). More recently, Sayle et al. (2013; 2014; 2016a; 2016b) used the isotope to elucidate animal movement and husbandry practice in Iceland, disentangle radiocarbon anomalies, and develop refined archaeological chronologies.

Stable isotope analysis involves measuring the ratios of carbon ($\delta^{13}C={}^{13}C/{}^{12}C$), nitrogen ($\delta^{15}N={}^{15}N/{}^{14}N$) and sulphur ($\delta^{34}S={}^{34}S/{}^{32}S$) isotopes in samples of bone collagen. Carbon isotopes are incorporated into plant tissues during photosynthesis, with the isotopic ratios ($\delta^{13}C$) varying significantly between plants depending on the route by which they fix atmospheric carbon (C_3, C_4, or CAM pathways). $\delta^{13}C$ values in plants can also vary between species (e.g. Feranec 2007). Therefore, within an animal population, $\delta^{13}C$ values can be used to distinguish between the consumption of C_3 and C_4 plants, but within a solely C_3 environment, such as prehistoric Britain, differences in foraging patterns and species preference can be deduced (DeNiro and Epstein 1978; Feranec 2007).

$\delta^{13}C$ displays a limited trophic shift between diet and consumer (~1.0‰) (DeNiro and Epstein 1978), whereas the 3–6‰ diet-consumer shift in $\delta^{15}N$ makes this a good isotope for determining where a consumer lies on the food chain between herbivore and apex predator (O'Connell et al. 2012; Schoeninger and DeNiro 1984). Nitrogen is incorporated into plant tissue from the soils and/or by the intake of atmospheric N_2. Plants that fix nitrogen from the atmosphere (e.g. legumes) generally have lower $\delta^{15}N$ values than those that fix it from soil (DeNiro and Epstein 1981). $\delta^{15}N$ values can be affected by environmental stressors, such as aridity (Ambrose 1991) and salinity (Britton et al. 2008), as well as cultural practices, such as manuring (Bogaard et al. 2007). $\delta^{15}N$ is useful, alongside $\delta^{13}C$, for deducing feeding preferences and foraging behavior among animals within a given environment.

Sulphur isotopes are site specific, with limited trophic level shifts of 1–1.5‰ (Peterson and Howarth 1987; Richards et al. 2001). They can be linked to diet in two primary ways: 1) weathering of local bedrock and drift geology releases sulphur into the soil, which is taken up into the roots of terrestrial and aquatic plants, and 2) by artificial enrichment of coastal vegetation through what is known as the 'sea spray effect' ($\delta^{34}S$ seawater = +21‰ approx.) (Rees et al. 1978; Wadleigh et al. 1994). The scale of the sea spray effect across Britain is not well understood, but it has been shown to cover >100 km in Ireland (Zazzo et al. 2011).

While $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ are often used in studies of individual movement across a landscape (Eckardt et al. 2014; Evans et al. 2006; Minniti et al. 2014; Viner et al. 2010), the fact that these analyses are not made on the same material that is being radiocarbon dated requires they form part of an additional study, or line of analytical enquiry. $\delta^{34}S$ is measured on the same prepared bone collagen used for the $\delta^{13}C$ and $\delta^{15}N$ measurements that inform the reconstruction of palaeodiet and ^{14}C-dating quality control. Furthermore, newer instrumentation (e.g. ThermoFisher IsoLink™, Elementar vario MICRO cube) allows for all three isotopes to be measured at the same time, thus enabling the routine measurement of $\delta^{34}S$ to be made in radiocarbon laboratories that are suitably equipped. Finally, the site-specific nature of $\delta^{34}S$ makes it a powerful tracer for residence and mobility in both animal and human populations, making it an excellent complementary isotope to $^{87}Sr/^{86}Sr$ and $\delta^{18}O$. The downside to $\delta^{34}S$ is our current lack of understanding about the spatial variation, resulting in its utility as a relative tracer. However, the low cost for pretreatment and measurement, when compared to $^{87}Sr/^{86}Sr$, means $\delta^{34}S$ can be used for characterizing large populations during a study that then uses $^{87}Sr/^{86}Sr$ to more closely refine the provenance of the defined groups.

2.3 Previous application of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ to Iron Age Britain and the Danebury environs

Carbon and nitrogen stable isotopes have been widely applied in palaeodietary studies of Iron Age human populations across Britain (Jay and Richards 2006; 2007; Lightfoot et al. 2009; Richards et al. 1998). Two studies on material from Danebury and sites in its environs (Stevens et al. 2010; 2013a) focused on the human populations, while a third was aimed more squarely at the variation identified in the diet of the animal populations from the Danebury sites (Stevens et al. 2013b). Traditional archaeological questions of mobility in Iron Age peoples have tended to focus on migratory movements of entire populations, with either material culture and more recently radiogenic strontium ($^{87}Sr/^{86}Sr$) analysis on people and animals providing evidence. However, stable isotopes of sulphur can be used to trace not only the movements of groups, but also the more mundane movement of individuals throughout their life. Despite this, there have been very few stable isotope-based investigations that directly look at mobility within Iron Age British human or animal populations. Until now, only the work of Jay et al. (2013) on the 'Arras culture' burials of East Yorkshire has included sulphur isotope measurements in a study of a British Iron Age human population, while no known study has applied the technique to faunal remains of this period.

2.4 Danebury and Suddern Farm

Danebury hillfort is situated on a hill in the rolling landscape of the Wessex chalkland at an elevation of *c*. 143 m. The hillfort lies 3 km west of the River Test, and approximately 4 km east of the Wallop Brook. Danebury sits on the highest point within the confines of is natural region, visible from many of the non-hillfort sites in its environs.

Suddern Farm is sited on a low spur of chalk (~85 m above sea level) approximately 4.5 km west of Danebury hillfort and is surrounded by three ditches that are roughly curvilinear in plan. Two of the ditches are substantial and measure approximately 4–5 m wide across the top and are about 10 m apart. The third is narrower and has been interpreted as a palisade trench. The site is of particular interest both because it is larger than the typical enclosed farmstead in Wessex (Fig. 1), as defined by the site of Little Woodbury (Evans 1989), and because the excavations revealed a large inhumation cemetery in an associated quarry hollow. The cemetery was originally thought to coincide with a period of abandonment of the settlement, but the radiocarbon dating indicates a substantial overlap.

2.5 The environmental setting

Today, the environment around Suddern Farm and Danebury hillfort is a mixture of arable and pasture, very probably not dissimilar from the Iron Age landscape. The superficial deposits of clay with flint are both highly dispersed and localized. The bedrock is almost entirely Upper Cretaceous white chalk with fine veins of limestone. This chalk formation cuts across a wide swath of southern Britain from Dorchester in the south-west, north of London to Cambridge and Norwich, doubling back up the east coast through Lincolnshire and East Yorkshire to just south of Scarborough (Figs. 2 and 3). The nearest non-chalk bedrock is a clay, sand and silt of the Lambeth and Thames Groups, approximately 9.5 km south towards the Solent. These two formations are also encountered moving away from the coast towards Reading, some 25 km distant to the north. At the shortest distance, the coast is approximately 45 km away, and this is again heading south toward the Solent.

3 Methods

3.1 Bone and tooth collagen preparation

A modified version of the Longin (1971) method was used to extract the collagen component from 71 bone and tooth dentine samples from animal remains at Suddern Farm and Danebury. Bones were initially cleaned using a Dremel® multi-tool, before being lightly crushed into smaller fragments. Tooth crowns, containing the primary dentine, were removed using the Dremel® multi-tool. Samples were immersed in 1M HCl at room temperature for approximately 24–48 hr to effect demineralized. The acidic solution was decanted, and the gelatinous-like material was rinsed with ultrapure water to remove any remaining dissociated carbonates, acid-soluble contaminants, and solubilized inorganic components. The material was immersed in ultrapure water and heated gently to ~80°C to denature and solubilize the collagen. After cooling, the solution was filtered, reduced to ~5 mL, and freeze-dried.

3.2 Tooth enamel preparation

The crown of the tooth was detached from its root, placed in a 10 M NaOH solution, heated to ~80°C for 8 hrs, and then allowed to cool. The dentine was scraped from the enamel using a dissecting needle and the procedure repeated until all the dentine had been removed. The sample was then repeatedly rinsed with 0.5 M HCl to remove all traces of NaOH, rinsed with ultra-pure water, and oven dried overnight.

3.3 Stable and radiogenic isotope measurements

$\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ stable isotope measurements were carried out using a Thermo Scientific Delta V Advantage isotope ratio mass spectrometer, coupled to a Costech ECS 4010 elemental analyzer. Samples were weighed into tin capsules (~600 µg for $\delta^{13}C$ and $\delta^{15}N$ and ~10 mg for $\delta^{34}S$) and were measured as described in Sayle et al. (2013). Results are reported as per mil (‰) deviations, relative to the internationally accepted standards V-PDB, AIR, and V-CDT for $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$, respectively, with 1σ precisions of ±0.2‰ ($\delta^{13}C$), ±0.3‰ ($\delta^{15}N$), and ±0.6‰ ($\delta^{34}S$).

Following enamel dissolution, strontium was isolated using conventional cation exchange methods and loaded onto single Re filaments using a Ta_2O_5 activator for mass spectrometry. The total procedural blank was < 200 pg. The samples were analysed on a VG Sector-54 Thermal Ionisation Mass Spectrometer (TIMS), operated in dynamic (3 cycle) multi-collection mode. Instrumental mass fractionation was corrected to $^{86}Sr/^{88}Sr = 0.1196$ using an exponential fractionation law. Data were collected as 12 blocks of 10 ratios. NIST SRM-987 was used as a quality control monitor.

4 Results

Stable isotope measurements were made on cortical bone collagen and tooth dentine from 28 terrestrial mammals from Suddern Farm and 43 terrestrial mammals from Danebury. They represented articulated individuals, many of them buried as complete skeletons, identified as possible samples for radiocarbon dating in the *(Re)Dating Danebury* project. In total, 14 of the Suddern Farm animals and 25 of the Danebury animals were radiocarbon dated. All but three of the undated animals came from pit fills that had other radiocarbon-dated material or pottery indicating an Early–Middle Iron Age date for the deposit (*c.* 400–200 BC). The remaining three samples dated to a period overlapping but continuing just after 200 cal BC. The terrestrial mammals for Suddern Farm included cow (n=10), horse (n=7), sheep (n=6), pig (n=4), and dog (n=1). The animals from Danebury included cow (n=18), horse (n=9), sheep (n=15), and red deer (n=1). The full dataset is available in S.I. Table 1.

$\delta^{13}C$ and $\delta^{15}N$ values for the terrestrial mammals at Suddern Farm and Danebury show a degree of variability that is not altogether unexpected for animals with diets comprising variable quantities of grasses and low-lying herbaceous plants (Fig. 4 upper). The mean $\delta^{13}C$ values are: cattle = −21.8 ± 0.4‰; sheep = −21.4 ± 0.3‰; and horse = −22.5 ± 0.4‰. The mean $\delta^{15}N$ values are: cattle = 4.1 ± 1.4‰; sheep = 5.0 ± 1.2‰; and horse = 4.2 ± 1.1‰. The mean $\delta^{34}S$ values are: cattle = 15.1 ± 4.2‰; sheep = 15.7 ± 3.9‰; and horse = 12.6 ± 4.5‰. There is a high degree of variability in the $\delta^{34}S$ measurements that is apparent when viewing plots of the $\delta^{13}C$ or $\delta^{15}N$ values against $\delta^{34}S$ (Figs. 4: middle and lower). Because $\delta^{34}S$ values reflect the underlying geology, these differences can be attributed to differences in the geographic regions where the animals were raised.

A cluster analysis using cosine similarity was run on the terrestrial herbivores (cow, horse, and sheep). The result indicates three distinct groups (Fig. 5). Group 1 (black) is the dominant population and is considered here to represent locally reared animals, or those animals that would have been raised within 5 km of the settlement (cf. Chisholm 1962; Higgs and Viti-Finzi 1972). Group 2 (red) comprises animals with the $\delta^{34}S$ values that diverge the most from the local group; they are presumed to be a non-local population reared off the chalkland and brought to the sites prior to death and burial. Group 3 (yellow) is formed of sheep and horse with $\delta^{34}S$ values in between the local and non-local population. This group could represent a population reared in another non-chalkland area or animals that regularly ranged between the chalkland and the region from where Group 2 originated, thus deriving a stable isotope signature that is a mixture between the local/non-local endmembers.

Two cows (GU-37419: P88 and GUsi-3989: P135) from Suddern Farm and one (GU-34917: P2382) from Danebury produced far lower $\delta^{34}S$ values than the other 25 cows. The tooth enamel from GUsi-3989: P135 was processed for strontium analysis. The result (0.711825 ± 0.0015) is similar to a horse tooth from the Iron Age site of Rooksdown, Hampshire (Bendrey et al. 2009), and suggests the cow was reared from as near as 150–200 km from the sites, in South Wales. A horse (GUsi-4869: P562) and a sheep (GUsi-4846: P361) from Danebury also fall into this 'non-local' Group 2. These results amount to 11% of the cattle population sampled (n=28) being reared non-locally, while 5% and 6% of the sheep (n=21) and horse (n=16) population, respectively, were non-local.

Group 3 includes two sheep from Danebury (GUsi-4843: P2567; GUsi-4848: P368) and one from Suddern Farm (GUsi-3990: P194), along with three horses from Danebury (GUsi-4866: P2273; GUsi-4867: P2320; GUsi-4868: P1481) and two from Suddern Farm (GU-37423: P122; GUsi-3993: P197). This amounts to 14% of the sampled sheep population (n=21) and 31% of the horse (n=16). Taking the two sites separately, the incidence of sheep from Groups 2 and 3 is almost equal at Danebury (20%) and Suddern Farm (17%), whereas more Group 2 and 3 horses occur at Danebury (44%) than at Suddern Farm (29%).

5 Discussion

The range of $\delta^{34}S$ values for the 'local' Group 1 (12.9–18.8‰) is in concordance with the data Jay et al. (2013) considered 'local' for Iron Age humans and animals from Wetwang Slack (13.0–16.5‰), which is on the same chalk formation in East Riding of Yorkshire. The slightly enriched $\delta^{34}S$ values observed in the Wessex data could be the result of differences in either the background variability within these two environments or in the samples themselves, with the Jay et al. (2013) values almost entirely from human burials and the data presented here from animals. While the cluster analysis results are presented as a potential cline between local and non-local, in reality any of the animals in Groups 2 and 3 could have been reared off the chalkland, or spent their lifetime moving between the chalkland and other isotopically distinct regions, thus developing some middle-ground $\delta^{34}S$ signature. For the sheep, this type of movement is suggestive of transhumance pastoralism with ranges covering broad swathes of land. For the horses, it is perhaps more likely that these animals were used for transport, moving people and goods between Danebury and Suddern Farm to settlements on other geological formations, and the age profiles of the horses at both sites support this conclusion. The effect, in both cases, would be to average their values over the areas they lived and traveled. The nature of cattle farming and the distances from which they might have come, suggest these animals were moved from off the chalkland to the Danebury area late in their lives.

The variability in $\delta^{13}C$ and $\delta^{15}N$ observed among the terrestrial herbivores from Suddern Farm and Danebury is similar to the results of Stevens et al. (2013b). They presented two broad hypotheses to explain these results: 1) that some of the animals were driven over long distances from isotopically-distinct lands; and 2) that the variation was the result of animal management through corralling and penning within distinct local 'isozones' in the near vicinity of Danebury. They chose the latter model, which supports the view that the animals were raised locally, considering the required level of population mobility to support the long-distance trade networks over a few hundred years as highly improbable.

The current study has identified 13 of 65 herbivores (~20%) from Danebury and Suddern Farm that were either raised on a different geology or had moved between the chalk and other areas. The results indicate a much higher degree of mobility in the period than previously considered likely or indicated by other studies (Stevens et al. 2013a; 2013b; Jay et al. 2013). In fact, it is precisely this high level of non-local and/or mobile terrestrial herbivores, picked up in the $\delta^{34}S$ values, that can account for the increased variability observed in the $\delta^{13}C$ and $\delta^{15}N$ values within groups of animals. When the $\delta^{13}C$ and $\delta^{15}N$ values for Group 1 are compared with Groups 2 and 3 combined the results for the two populations are statistically significantly different (Student's t-test: $\delta^{13}C$: $p = 0.0002$; $\delta^{15}N$: $p = 0.0026$). Looking at the plot of $\delta^{13}C$ against $\delta^{15}N$, coded for local versus non-local/mixed animals, we see a relatively high degree of variation in both groups (Fig. 6). If the dataset of Stevens et al. (2013b) could allow for the same discrimination, their interpretations regarding local animal management regimes might not change. Ultimately, there is no need to choose between the two hypotheses, since local management practices could have resulted in some animals being corralled and penned in distinct 'isozones', while others were moved throughout their lives between isotopically distinct regions, and others still were brought to Danebury and Suddern Farm from other isotopically distinct areas.

6 Conclusions

The research presented here, using animals as a proxy, demonstrates the degree to which Iron Age people in the period 400–200 cal BC were mobile. We suggest that the paradigm that views Iron Age people as leading a relatively sedentary life should be re-evaluated, and new models, that allow for regular movements by a portion of the population over distances exceeding 100 km, be considered. More direct studies on human populations are required for untangling whether the mobility of the animals is linked to a small group of individuals moving animals as part of a wider system of trade/exchange or if this is indicative of the mobility of a broader portion of the population. While the proportion of mobile individuals could remain relatively small, with this increased scale in their spheres of interaction, these 'Celtic cowboys' have far greater possibilities for contact between different groups, thus expanding the complexity of their network of relations.

Additionally, although maps for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ exist across Britain and much of the continent, there is a definite need to better understand the variability of $\delta^{34}S$ across the broader landscape. While the $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ isoscapes have been constructed using either modern materials or a combination of modern and archaeological samples, a $\delta^{34}S$ isoscape is reliant on archaeological samples (Richards et al. 2001). Over time, studies on archaeological material, where $\delta^{34}S$ values are routinely measured, will contribute towards the development of $\delta^{34}S$ isoscapes, which can be used alongside the continually developing isoscapes for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, thereby enhancing the interpretative power of these geo-locational isotopic analyses by allowing us to more readily trace the movement of animals and people through life. To that end, $\delta^{34}S$ should be analysed routinely in stable isotope studies of palaeodiet, as well as when undertaking large programmes of radiocarbon dating, so that the geographic origin of the people and animals in the past can be better understood, and further investigated using the better spatially-defined $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analyses.

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Figure captions

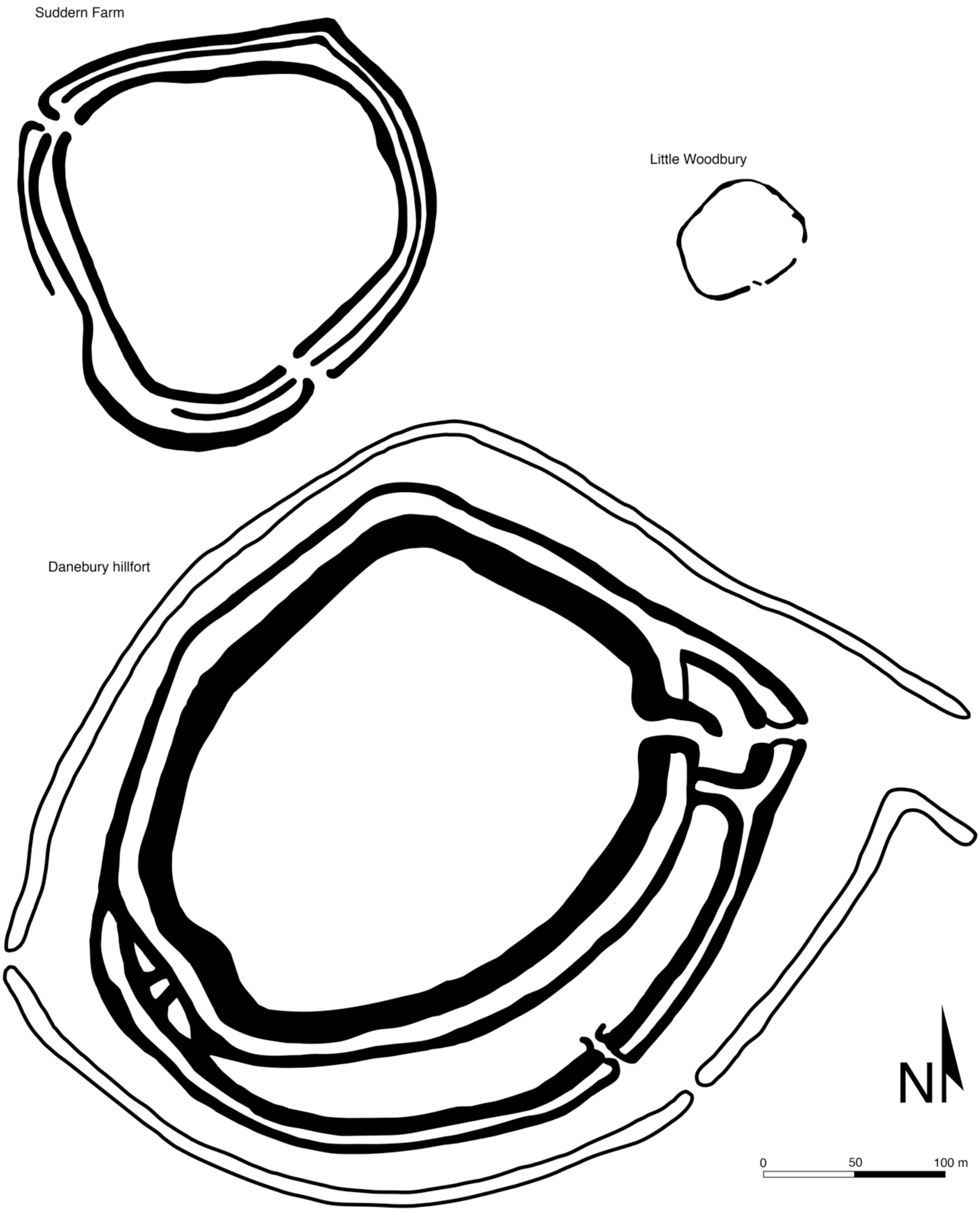

Figure 1: Plan of Danebury hillfort and Suddern Farm alongside Little Woodbury, a 'typical' Iron Age enclosed settlement in Wessex. Redrawn from various sources.

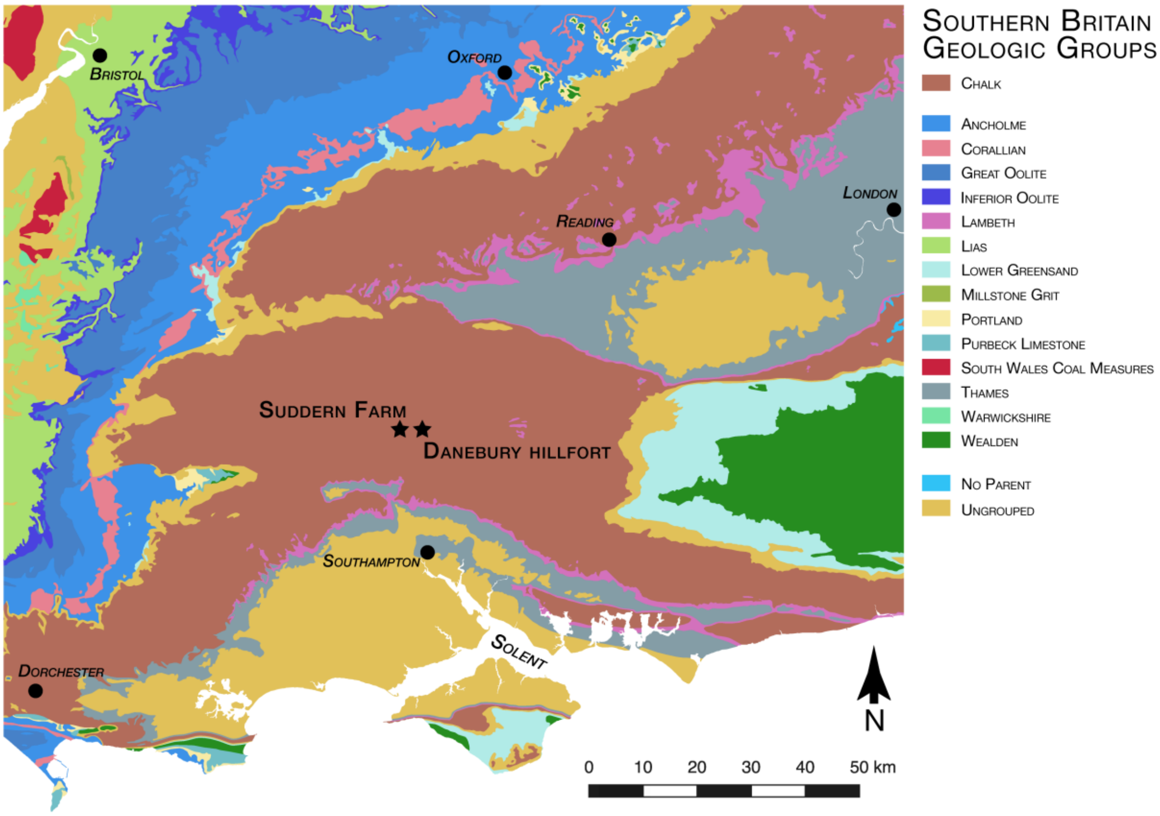

Figure 2: Map of Britain showing the location of Danebury hillfort and Suddern Farm in relation to the bedrock geology of Britain (Based upon the DiGMapGB-625 dataset, with the permission of the British Geological Survey)

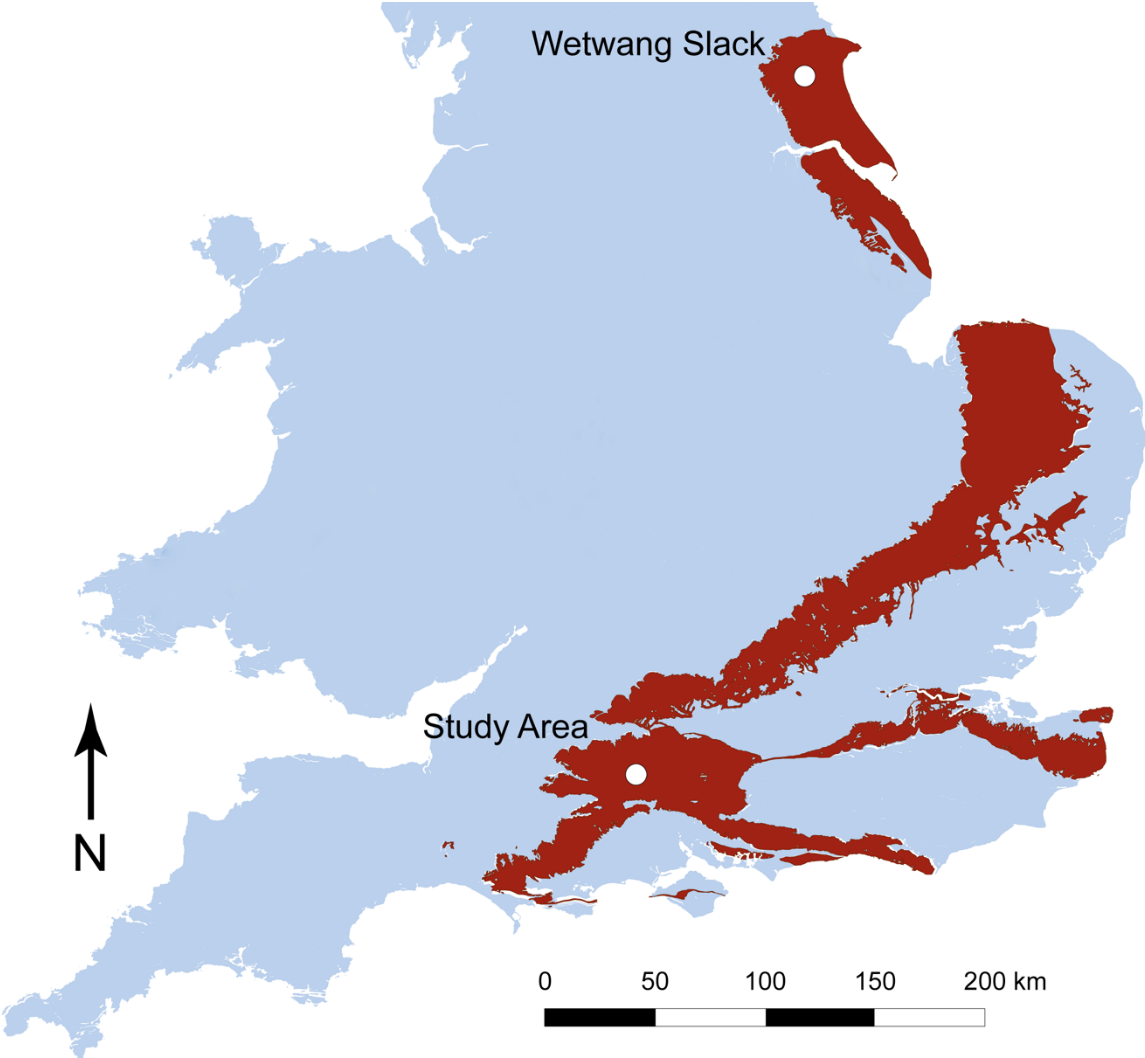

Figure 3: Map showing the location of the Study Area and site of Wetwang Slack, where Jay et al. (2013) undertook $\delta^{34}S$ analyses on Iron Age human and fauna remains, in relation to the band of white chalk and the coast (Based upon the DiGMapGB-625 dataset, with the permission of the British Geological Survey)

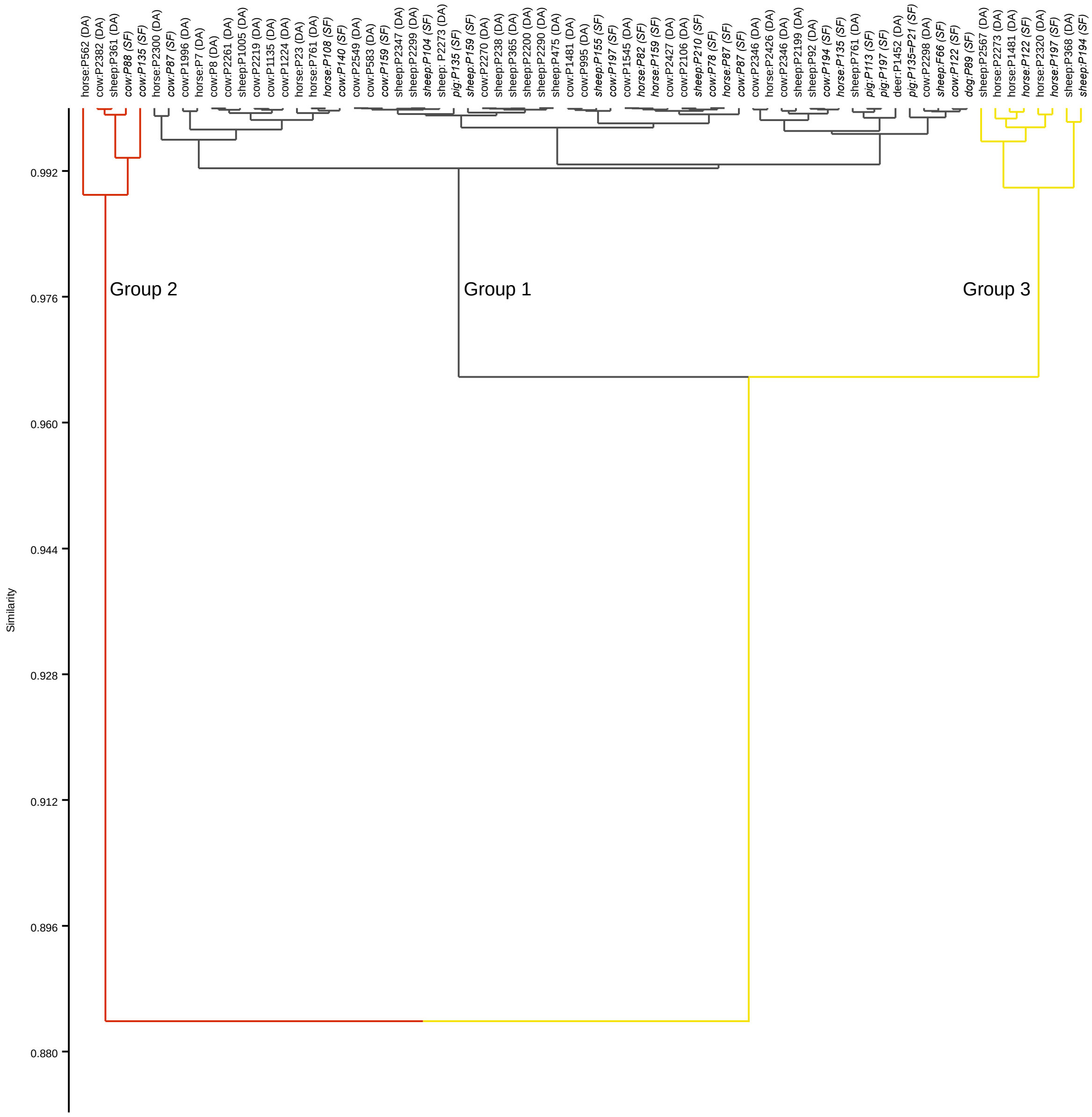

Figure 4: Plots of δ^{13}C, δ^{15}N, and δ^{34}S for Danebury hillfort and Suddern Farm animal bone and teeth collagen – **(upper)** δ^{15}N vs δ^{13}C; **(middle)** δ^{34}S vs δ^{13}C; and **(lower)** δ^{34}S vs δ^{15}N. The red band represents Group 2 in Figure 5 and the yellow band represents Group 3.

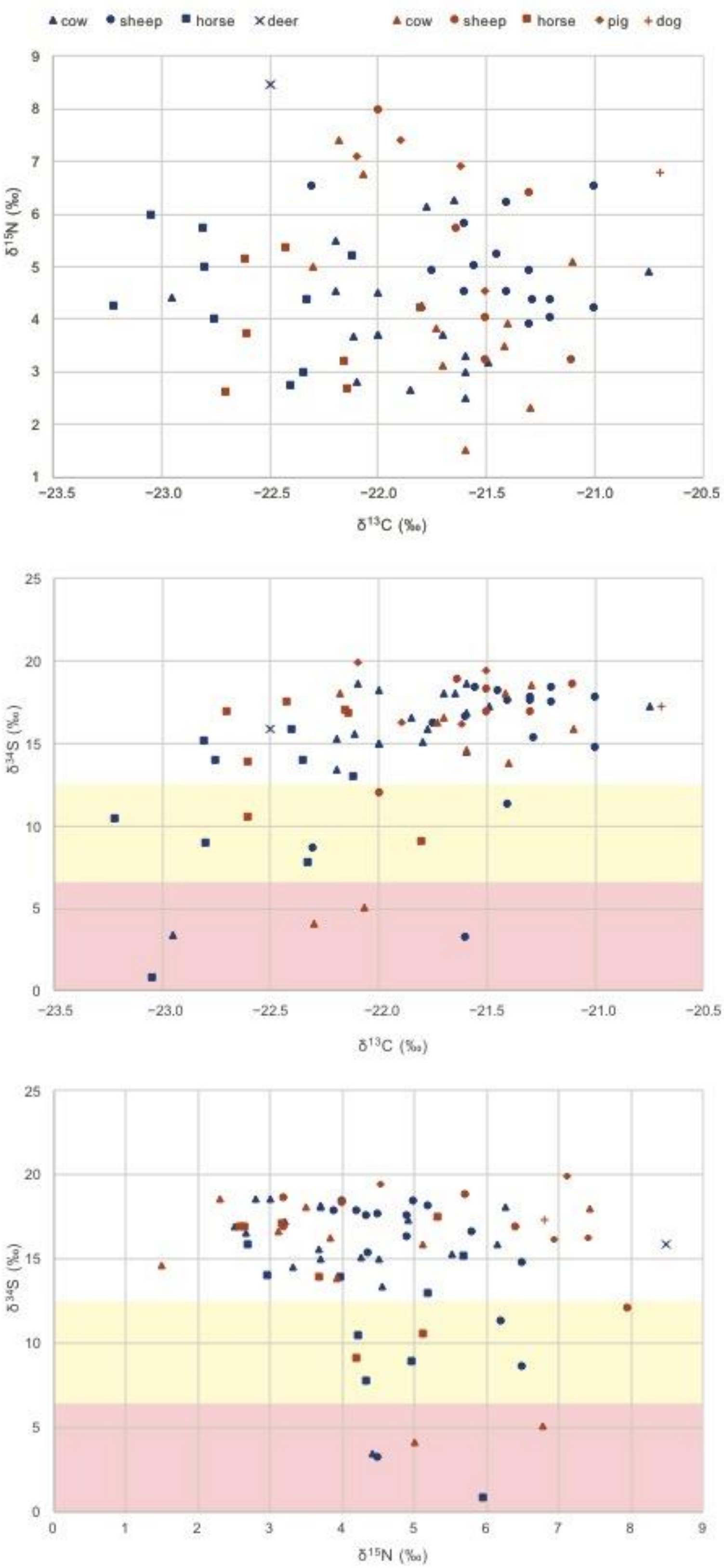

Figure 5: Result of cluster analysis showing the three groups. Group 1 is the local animal population, while Group 2 is the non-local animals, and Group 3 represent animals with either a non-local or mixed isotopic signature.

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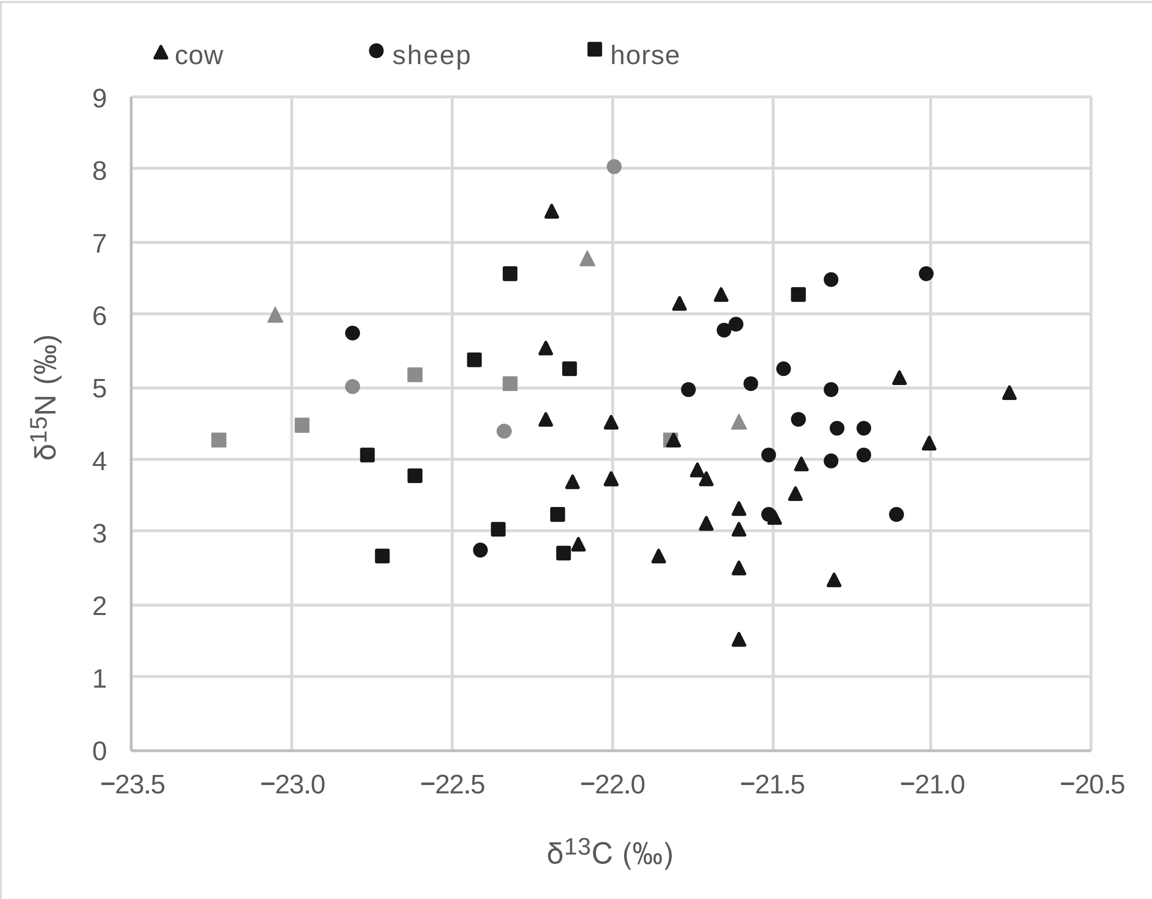

510 **Figure 6:** Plot of $\delta^{13}C$ versus $\delta^{15}N$, separated as Group 1 (local: black) and Groups 2 and 3 (non-
511 local/'mixed': grey).

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